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Indonesian LCM Evaluation Tests Using a Modified API Bridging-Materials Tester

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Abstract

The Geothermal Research Department at Sandia National Laboratories has been testing and evaluating lost circulation materials since 1982. A standard API Slot Tester has been modified to improve the reliability of this testing and a baseline for mud and bridging-material distribution was established. A recent request was made by the drilling industry for evaluation tests on lost circulation material currently being used in geothermal drilling operations in Indonesia and the Philippines. Sandia test equipment was reassembled and a series of tests were conducted. This report documents the results of these evaluation tests on the new materials when they were added to standard water-based bentonite mud, containing walnut shells, and used to plug a simulated loss zone.

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Background:

Evaluation testing of lost circulation materials has been carried out by the Geothermal Research Department at Sandia National Laboratories since 1982. A standard API Bridging Materials Tester was modified by Sandia¹ in an effort to improve the reliability of static (no mixing during test) Lost Circulation Material (LCM) testing. A large number of LCM evaluation tests were conducted at Sandia using this modified bridging-materials tester and the results reported². As a result of this work, the geothermal drilling industry asked Sandia to conduct similar tests on new lost circulation materials currently in use in Indonesia and the Philippines.

Test Procedures:

The modified API bridging-materials tester had been dismantled and placed in storage after a series of LCM tests were completed in 1990. This equipment was removed from storage, cleaned and re-certified for testing. The re-certification included replacement of all seals and pressure testing of all components for compliance with current safety requirements. The data acquisition computer used during these tests was also upgraded to current standards. An operating procedure was prepared for testing the Indonesian LCM and the Pressure Data Package was updated to reflect changes as a result of the re-certification.

To establish a baseline for evaluating the Indonesian LCM, a series of tests were conducted using a standard water-based bentonite mud (apparent viscosity 21cp) containing a SAN2 particle size distribution of ground walnut shells. The SAN2 particle size mix contains a high percentage of larger particles and this distribution was chosen by Sandia, during previous LCM testing, as the baseline for all material tests. We selected our walnut shell size distribution from three commercial bag sizes: fine (30/100 mesh), medium, (12/20 mesh) and coarse (8/12 mesh). These were mixed at a ratio of 15 pounds per barrel of walnut shells containing 4.5 pounds of fine shells, 7.35 pounds of medium shells and 3.15 pounds of coarse shells. In accordance with the SAN2 distribution, this mixture had a concentration of approximately 21% of the larger size particles.

This mixture was then placed into the API bridging-materials tester test vessel and forced, by a nitrogen-gas-pressure-driven piston, through a 6" deep X 1.250" high X several selected widths wide slot. Slot widths were selected to be 200, 150, 125, and 100% of the size of the average coarse walnut shell particle. For these tests the slot widths used were 0.160", 0.120", 0.100", and 0.080" respectively. The nitrogen gas pressure was increased in 100 psi increments until the entire mixture was forced through the slot and into the tester receiver, or until the LCM bridged the slot and the nitrogen gas pressure reached or exceeded 500 psi. The amount, if any, of the mixture forced into the API tester receiver was recorded to document the effect of the LCM seal across the slot.

After the baseline was established, the Indonesian LCM was added to the test mixture containing the walnut shells and the tests were repeated in an attempt to bridge-off and seal slots that failed to seal with the walnut shell mix alone. Two types of Indonesian

LCM were evaluated separately; in addition, both types were added to the same mixture for evaluation.

Baseline Testing Results:

The test LCM performed best in the Philippines when it was used while drilling with rock chips in the drilling mud. To model this condition walnut shells were added to the mud for evaluating the new LCM in the modified API tester. Baseline testing began by using the smallest (0.080") width slot. A series of three tests were conducted for each slot width. If the walnut shell mixture bridged and held 500 psi the slot width was increased to the next size and the series of three tests repeated. Figure 1 shows a plot of the

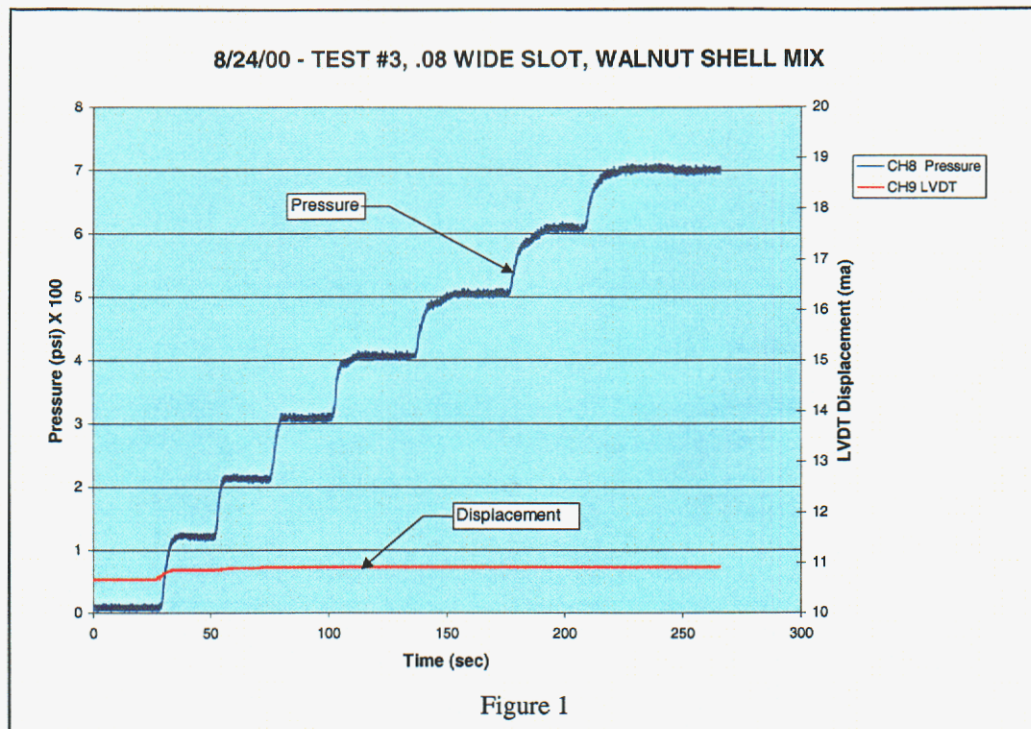
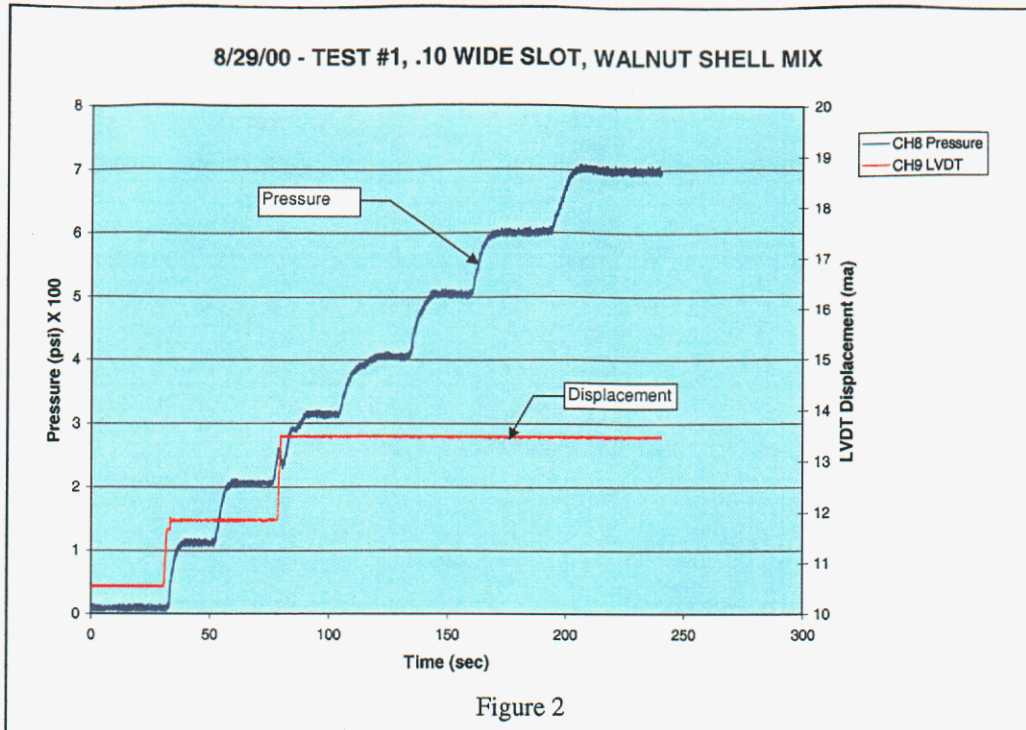


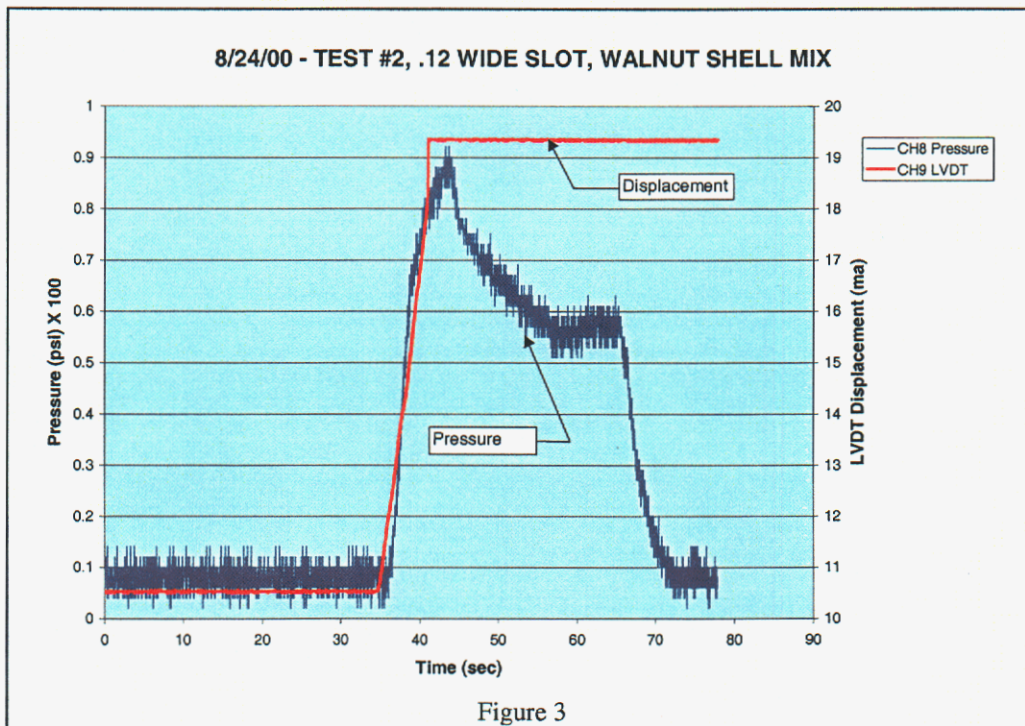
Figure 1

pressure and fluid displacement into the receiver vessel vs. time as the fluid is being forced through the 6.0" deep X 1.250" high X 0.080" wide slot. As shown, the mixture leaked slowly through the bridged slot as the pressure was initially increased but the bridge formed quickly and did not break down when the pressure was increased up to 700 psi. After the initial leak the slot sealed and remained sealed throughout the test. The initial offset of the Liner Variable Differential Transformer (LVDT) used to measure filtrate volume on the Modified API Tester was a constant, thus the displacement because of the leak is the differential shown.

The slot size width was increased to 0.100" and the three tests were repeated with the walnut shell mix. Figure 2 is a plot of this test. As shown, more of the mixture flowed through the slot initially before the bridge was formed. A second leak occurred when the pressure was increased from 200 psi to 300 psi, but the bridge resealed and remained sealed as the pressure was increased up to 700 psi.



The slot size width was again increased, this time to 0.120". The series of three tests with the walnut shell mix were again repeated. Figure 3 shows that the mixture did not bridge the slot, but flowed through rapidly (approximately 35 seconds) as the pressure was being raised to 100 psi. The peak pressure was less than 90 psi when all of the fluid mixture in the test vessel was displaced into the receiver vessel. Since the walnut shell mixture

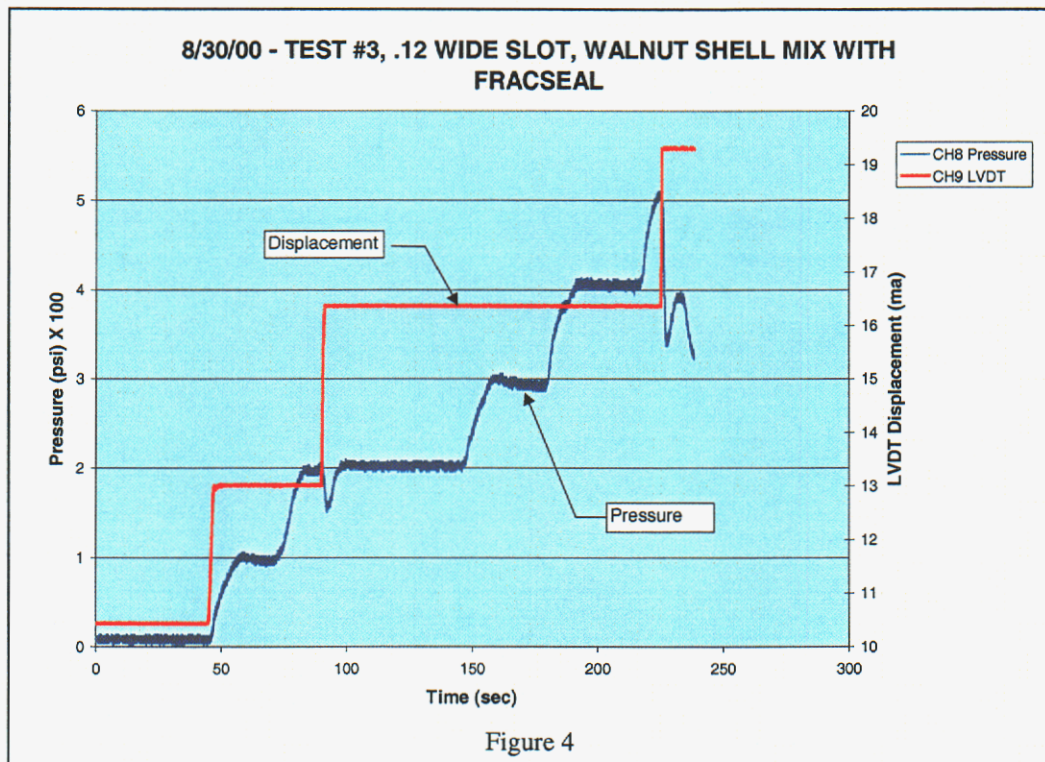


could not bridge the 0.120" wide slot and since the Indonesian LCM should add to the bridging and sealing capability of our mixture, the 0.120" slot size was judged to be best for evaluating the new LCM.

LCM Testing Results:

The LCM supplied to Sandia for evaluation is made from the bark of Indonesian trees. It is marketed by PT OBM DRILLCHEM under the trade names of FRACSEAL and SANDSEAL. Three series of three tests each were planned, one each with either FRACSEAL or SANDSEAL and one with both FRACSEAL and SANDSEAL added to our mixture.

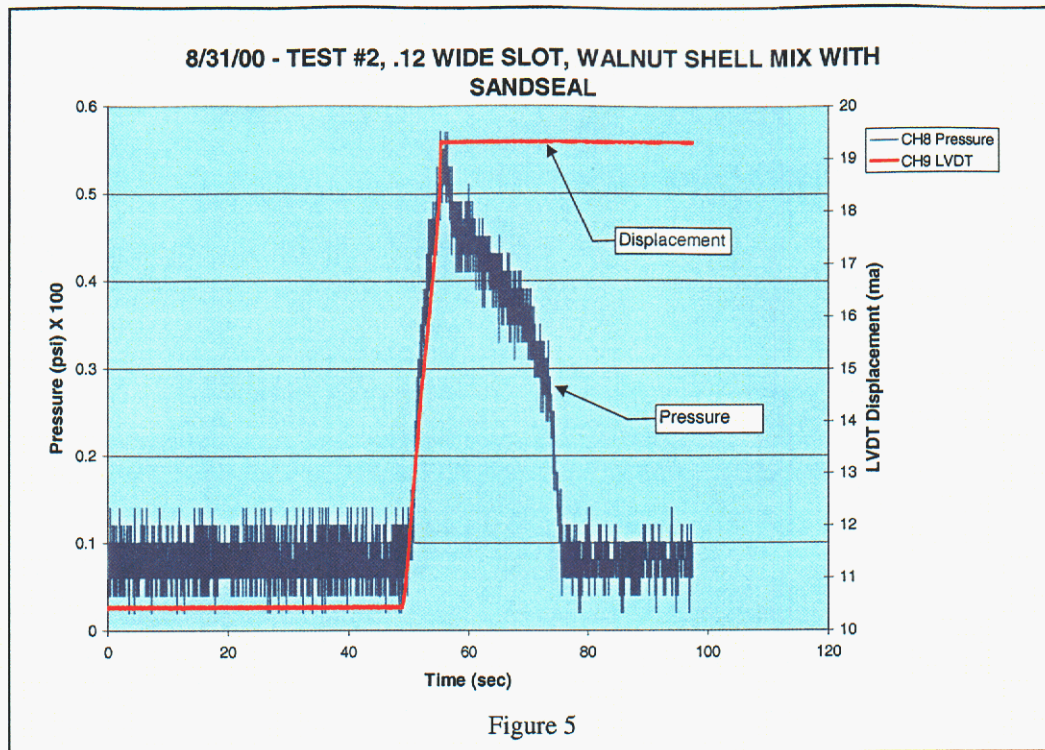
The first series of tests were conducted with FRACSEAL added to our walnut shell mixture at a ratio of 20 pounds per barrel. The first two tests, in this series, showed no improvement over the mixture without the FRACSEAL. However, as shown in Figure 4, the third test did indicate that the mixture bridged the 0.120" wide slot and provided a



temporary seal up to 500 psi. A small leak occurred at 200 psi, but resealed and held until the pressure was increased up to 500 psi where a large leak resulted in displacing all remaining fluid in the test vessel. This test showed some improvement in sealing lost circulation with FRACSEAL over our baseline mixture, but overall the FRACSEAL was not consistent in sealing the 0.120" wide slot.

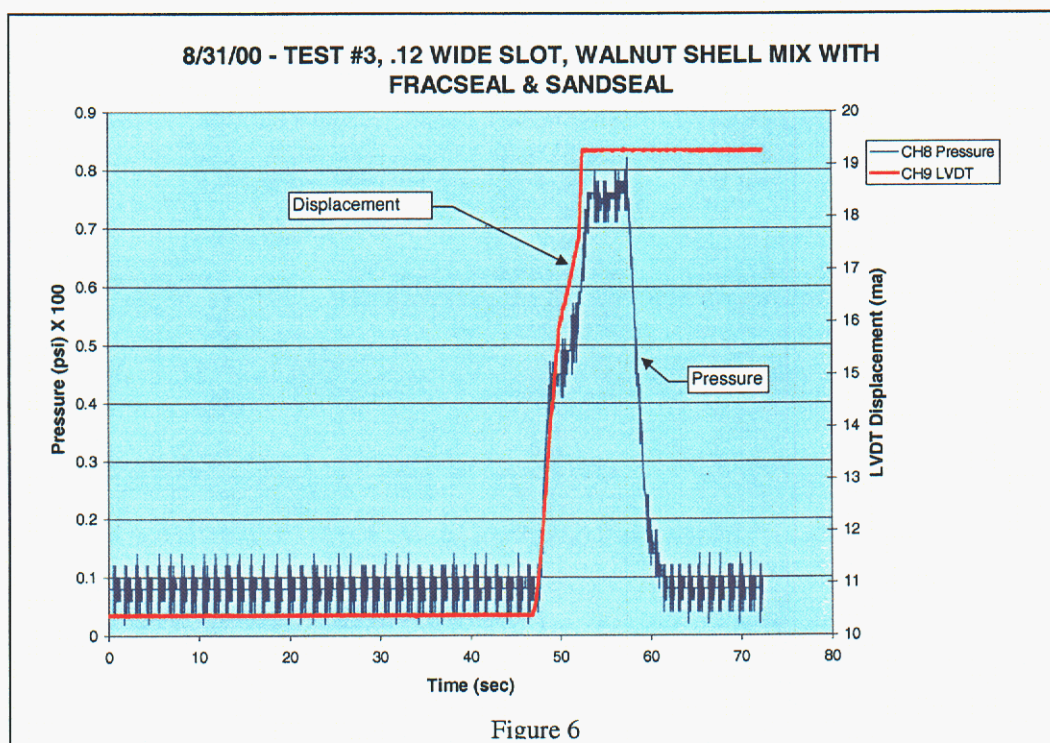
The second series of tests were conducted with SANDSEAL added to our baseline walnut shell mix. The SANDSEAL was also added to our mixture, at a ratio of 20 pounds per barrel. The three tests in this series showed no improvement over the mixture

without the SANDSEAL. Figure 5 below shows the results of test number two in this



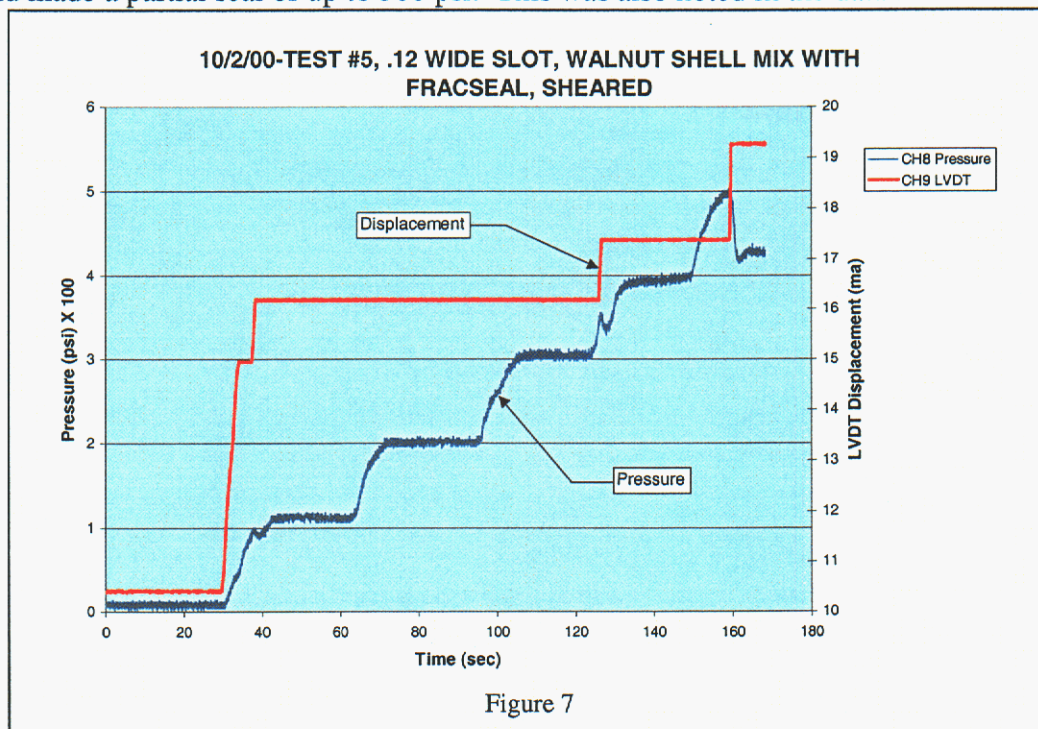
series and is typical of the tests done without the SANDSEAL.

A third series of tests was completed with both FRACSEAL and SANDSEAL added to our baseline mixture, each at a ratio of 20 pounds per barrel. Again, test results showed little improvement over the baseline mixture. Figure 6 shows a plot indicating that some



bridging may have started to form, but broke down rapidly even at low pressures. This plot was typical for this series of tests.

Results of the evaluation testing were discussed with an industry representative, Mr. Bill Rickard, of the Resources Group. He indicated that FRACSEAL in use in drilling operations in the Philippines is normally sheared when it is forced through the drill bit nozzles while drilling and this shearing action may improve the sealing capability of the LCM. To model this condition he suggested that the test mixture, with the FRACSEAL added, be blended in a commercial blender to shear the LCM prior to placing it in the modified API tester and attempting to bridge and seal the test slot. Another batch of baseline mixture with 20 pounds per barrel of FRACSEAL was prepared and stirred in a standard blender for several minutes to shear the LCM. A forth series of tests was then conducted to evaluate the sheared mixture. Again, the improvements as a result of adding and shearing the FRACSEAL were only minor, but the shear effect could be measured. The average breakdown pressure increased from about 50 psi in the unsheared test samples to greater than 100 psi after shearing. However, this was not considered to be a significant improvement in the LCM for bridging and sealing the 0.120" wide slot. As shown in Figure 7, one of the three tests in this series did bridge the 0.120" wide gap and made a partial seal of up to 500 psi. This was also noted in the data from the



unsheared FRACSEAL testing, but again the sheared FRACSEAL did not provide the consistent improved sealing results expected.

Table 1 below is provided to summarize test conditions and compare test results.

Table 1 - Test Summary

| TEST DATE & TEST # | SLOT WIDTH | TYPE LCM ADDED TO MUD | PEAK PRESSURE | FLUID DISPLACEMENT |
|--------------------|------------|--|---------------|--------------------|
| 8/21/00 - Test #1 | .080" | Walnut shells | 400 psi | ~5% |
| 8/24/00 - Test #2 | .080" | Walnut shells | 700 psi | ~2% |
| 8/24/00 - Test #3 | .080" | Walnut shells | 700 psi | ~3% |
| 8/29/00 - Test #1 | .100" | Walnut shells | 700 psi | ~33% |
| 8/29/00 - Test #2 | .100" | Walnut shells | 700 psi | ~13% |
| 8/29/00 - Test #3 | .100" | Walnut shells | 600 psi | 100% |
| 8/18/00 - Test #1 | .120" | Walnut shells | 70 psi | * |
| 8/24/00 - Test #2 | .120" | Walnut shells | 85 psi | 100% |
| 8/24/00 - Test #3 | .120" | Walnut shells | 80 psi | 100% |
| 8/30/00 - Test #1 | .120" | Walnut shells + FRACSEAL | 50 psi | 100% |
| 8/30/00 - Test #2 | .120" | Walnut shells + FRACSEAL | 35 psi | 100% |
| 8/30/00 - Test #3 | .120" | Walnut shells + FRACSEAL | 500 psi | 100% |
| 8/31/00 - Test #1 | .120" | Walnut shells + SANDSEAL | 45 psi | 100% |
| 8/31/00 - Test #2 | .120" | Walnut shells + SANDSEAL | 50 psi | 100% |
| 8/31/00 - Test #3 | .120" | Walnut shells + SANDSEAL | 40 psi | 100% |
| 8/31/00 - Test #1 | .120" | Walnut shells + FRACSEAL + SANDSEAL | 70 psi | 100% |
| 8/31/00 - Test #2 | .120" | Walnut shells + FRACSEAL + SANDSEAL | 90 psi | 100% |
| 8/31/00 - Test #3 | .120" | Walnut shells + FRACSEAL + SANDSEAL | 75 psi | 100% |
| 10/2/00 - Test #4 | .120" | Walnut shells + FRACSEAL After Shearing in Blender | 115 psi | 100% |
| 10/2/00 - Test #5 | .120" | Walnut shells + FRACSEAL After Shearing in Blender | 500 psi | 100% |
| 10/2/00 - Test #6 | .120" | Walnut shells + FRACSEAL After Shearing in Blender | 160 psi | 100% |

* - Test procedures were not followed, resulting in a displacement measurement error.

Field vs. Laboratory Response:

Experience with FRACSEAL and SANDSEAL while drilling geothermal wells suggests that they significantly reduce lost circulation problems over drilling with traditional mud (Bill Rickard, personal communication). Little difference was observed in the tests done with the modified API slot tester with or without FRACSEAL and SANDSEAL. This raises the question as to whether the laboratory tests adequately evaluated the potential of this lost-circulation material to plug loss zones. There are several differences between field and laboratory conditions: 1) the "pedigree" of the mud, 2) the "geometry" of the modified API tester, and the 3) the bridging agent used.

The mud used in the laboratory tests was prepared in an industrial ribbon blender according to standard mud engineering practices. The processes used for handling mud in the laboratory have been adequate for past lost-circulation material testing. However, there are several aspects of the field mud "pedigree" that cannot be readily duplicated in the laboratory. The tests were not conducted at elevated temperature and the aging and shear history of the mud in the laboratory is not the same as mud that has been circulated

in a well. While it is believed that these differences did not affect results, it is not possible to prove this premise.

Flow of mud in the modified slot tester is not the same as flow of mud in the wellbore. To address this issue a wellbore simulator was built at Sandia (see Reference #1.) that directed flow across a slot simulating a fracture. Considerable work was done to simulate actual wellbore geometry and flow conditions including elevating the temperature, applying a hydrostatic head, and roughening the slot surfaces to simulate wellbore conditions. Work done with that system demonstrated that the modified slot tester provides legitimate data for screening and comparing lost circulation materials; i.e., if the modified API slot tester did not show significant improvement using FRACSEAL or SANDSEAL, then it is not expected that the wellbore simulator would have either.

FRACSEAL and SANDSEAL are supposed to work in conjunction with a bridging agent. In the field, the bridging agent can be added lost circulation material or it can be drill cuttings. In theory, bridging can be one or two-particle bridging. In this work, a seal was only formed for a slot size of 125% of the average coarse particle size using the baseline mixture. This is less than expected. Walnut shells were chosen for the laboratory work to tie the baseline mixture to previous work. Cuttings, on the other hand, could have higher particle strengths that possibly allow the bridging of wider slots. While there is no particular reason to expect FRACSEAL and SANDSEAL would work better with cuttings than with our baseline mixture, this cannot be ruled out.

During the tests the "crushing" of the walnut shells could be heard when the bridge was being formed across the slot. The walnut shells used in our baseline mixture were ten years old and may have lost some of their particle strength. This could explain why seals were not made across the wider slots using the baseline mixture (two-particle bridging would suggest a slot size of 200%), but again this should not affect the comparison of bridging and sealing the slots with and without the FRACSEAL and SANDSEAL.

It should also be noted that, in the field, flakes or other "plastic" material is often added to walnut shells to enhance the plugging of the lost circulation zones. Adding such material is not expected to have an impact on the comparison of regular mud and FRACSEAL and SANDSEAL reported here, but this was not investigated.

Conclusion:

The Sandia modified API tester was reassembled and used to evaluate the FRACSEAL and SANDSEAL Indonesian LCM obtained from the drilling industry. These static evaluation tests were done at Sandia in the Building 851 mud laboratory. The procedures used for these tests were consistent with those used by Loeppke et. al., and as recommended in API RP 121, and with those suggested by Mr. Bill Rickard regarding the use of the FRACSEAL and SANDSEAL. The tests were conducted using a 6.000" deep X 1.250" high X 0.120" wide test slot. Data were recorded to document the bridging and sealing properties of the LCM when it was forced through the test slot under pressure. A baseline was established with a mud mixture selected to model geothermal drilling mud

under field conditions. The Indonesian LCM was then added to this baseline mixture and the differences compared.

Under our test conditions, no or only a slight improvement in the bridging and sealing properties of our baseline LCM mixture could be measured when FRACSEAL, SANDSEAL or both were added in the recommended ratios. A baseline mixture with FRACSEAL that was sheared in a blender prior to evaluation testing did demonstrate a slight increase in the bridging and sealing properties of the LCM. This small improvement, however, is probably not significant enough to justify the added cost of the FRACSEAL. It should also be noted that FRACSEAL and/or SANDSEAL were not evaluated using the smaller .100" wide slot. Therefore, we did not determine if the addition of these materials to our baseline mixture would reduce the filtrate when forming the sealed bridge plug. Filtrate reduction improvement could enhance the justification for adding these materials to the LCM mixture. Additional field-testing may be desirable to determine if, under different conditions, the addition of these products may offer greater improvement over the current industry standard LCM.

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2. G.E. Loeppke, D.A. Glowka, and E.K. Wright, 1990, "Design and Evaluation of Lost-Circulation Materials for Severe Environments," *Journal of Petroleum Technology*, March 1990, Pages 328-337.

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